Cancer Research Center Hotline

Radiation Oncology Update

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Summary

Recent technological developments in radiation oncology, enabled by high-speed computers, are allowing better target localization, faster throughput and more confined treatment delivery. Although available in only certain locations and beneficial for only selected cases, Intensity Modulated Radiation Therapy (IMRT) and Stereotactic Radiosurgery (SRS) represent exciting and revolutionary techniques of providing more concise doses of radiation to specifically targeted volumes while minimizing radiation to surrounding non-target tissues. IMRT and SRS, therefore, theoretically can improve control rates while lowering toxicity of radiation treatment. While the technology is less expensive and less logistically challenging than machines for neutron and proton delivery, increased time for treatment planning and quality assurance, financial feasibility and cost-effectiveness remain significant issues and have therefore limited more widespread application. Research continues on the use of chemotherapy and biologic modifiers to alter cell sensitivity to radiation, decrease side effects, and improve the therapeutic ratio. Potential applications are expanding for use of brachytherapy to prevent restenosis and in the treatment of brain, breast, and prostate neoplasms, but are presently limited by lack of mature studies and reimbursement issues. Due to the high costs of radiotherapy technology acquisition and equipment maintenance, increasing staff salaries and tenuous reimbursement environment, care should be taken to avoid unnecessary duplication of services in the community.

Historical Perspective

Technological breakthroughs are allowing for more selective dose delivery. Historically and for most cases today, radiation beams are used to treat patients from fixed angles through a single plane called a coplanar technique. At other times, treatment is delivered with the head of the linac rotating around the patient in arcs or using a non-coplanar technique with the table and machine gantry angled such that oblique beams enter the patient from different planes. The combination of multiple beams entering the patient from different angles provides higher doses of radiation to the target volume at the intersection of the beams relative to the surrounding tissues through which the beams enter and exit the patient. An analogy of this would be several spotlights pointed at a stage actor performing in a darkened auditorium. The target volume, in this case the actor, would be bathed in a higher intensity of light relative to other locations in the surrounding auditorium.

Traditionally, beams produced by the linacs are square or rectangular in shape with field sizes as determined by the treating physician. The size of the field is designed to include the target volume plus a margin to account for the infiltrative nature of malignant neoplasms in general, as well as, the physical drop-off in dose at the edges of the field, patient and organ motion. Shaped fields are created by using thick, heavy metal alloy cerrobend blocks with delivery of fairly even doses of radiation across the volume at given depths. The use of shaped combinations of fields is called 3-D conformal therapy and is presently available at all radiation facilities in Hawaii. Multileaf collimators are now replacing cerrobend blocking in many centers. Multileaf collimators use multiple, small (3 to 10 mm), blocking leaves or segments that can be moved in from the margins of the field to replicate shaped cerrobend fields. Two major advantages of multileaf collimation are that the radiation therapist doesn't need to lift heavy cerrobend blocks, some of which weigh up to 40 pounds, and the ability to perform IMRT.

Intensity Modulated Radiation Therapy (IMRT)

The advent of high-speed computers and multileaf collimation has allowed for even more complex treatment planning and for modulation of segments within the radiation beam by selectively blocking and unblocking portions of the field during treatment using coplanar fixed beams or rotational arcs. Using combinations of segmented beams entering the target from different directions, radiation plans can be generated to deliver extremely selective and heterogeneous intensity modulated radiation dose distributions within a target volume. Hence, instead of a homogenous, even dose distribution across the target volume, IMRT allows selective targeting to areas of specific concern with less radiation to normal adjacent tissues. Care must still be taken not to exceed radiation dose tolerance of critical organs. Since these organs can be partially shielded with IMRT, the total dose to the gross tumor volume can in some cases be safely escalated. Thus, tumor control rates may be improved, while side effects of normal organ radiation may be lowered.

Indications for the use of IMRT are expanding with current projections to include roughly 15% of all patients undergoing radiation treatment. At the present time, IMRT is commonly being used in Hawaii to treat cancers in the prostate, head and neck. Key concerns arising with IMRT are the potential for local recurrence and recurrences at the edge of the radiation field due to organ motion and underestimation of extent of involvement. Previously, simulation for radiation treatment planning was done on the treatment machine or with fluoroscopy units to anatomically identify target volumes as defined by pretreatment radiographic imaging with respect to their relation to skeletal and soft tissue landmarks. The advent of computed tomography (CT) planning allows the ability to image the patient in the treatment position for more accurate identification of target and critical organ volumes. Various external devices can be used for patient immobilization and better reproducibility of patient set up; however, internal organ motion remains an issue.

Software and technology being presently introduced into the marketplace and showcased at national meetings allows for fusion and nearly simultaneous data acquisition of CT with magnetic resonance imaging (MRI) and positron emission tomography (PET) scans to allow for even more selective targeting of radiation dose within a specified volume. Yet to be answered is the question of whether more is better, or will the combination of technologies only result in more shades of gray (no pun intended). New technology also exists to account for internal organ motion with respiratory gating, ultrasound and CT verification of positioning. In the case of respiratory gating, the beam can be switched off when the target move moves away from the beam, or in the case of the Cyber Knife, the treatment head can be moved in relation to the isocenter. Ultrasound and CT imaging equipment stationed in the treatment vault can be used to adjust treatment set up relative to the target volume. Limited practical applications and financial feasibility remain significant impediments to widespread acquisition of these technologies.

Stereotactic Radiosurgery (SRS)

The combination of multiple small caliber beams or arcs allows delivery of high doses to small (less than 3 cm diameter) target volumes with dramatic dose fall off, such that surrounding tissues are minimally radiated. The treatment is termed SRS when given as a single fraction or stereotactic radiotherapy (SRT) when fractionated over a period of time. SRS and SRT can be done with special modifications to the linac or with dedicated units, such as the Gamma Knife. The Gamma Knife is limited to intracranial applications, but has the potential advantage of delivering more heterogeneous dose distributions, which tend to be centrally hotter where cancer cells tend to be less oxygenated, more necrotic and less radioresponsive. With proper immobilization and localization technology, linac-based stereotactic radiosurgery has both intra- and extracranial potential application. But as most extracranial tumors generally involve larger volumes, SRS and SRT are generally reserved for primary brain neoplasms and certain functional disorders. The role of SRS in the treatment of brain metastases is not well defined, and treatment criteria are evolving. There is a growing database supporting its use instead of or in combination with whole brain radiation. Overall patient prognosis, performance status, number of brain lesions, and extent of systemic involvement are important considerations since SRS and SRT are costly.

Radiosensitizers and Radioprotectants

The list of chemotherapy agents to sensitize cancer cells to radiation continues to grow, and like much of medicine in the post Human Genome Project era will increasingly head toward the molecular level with agents that are more selectively targeted. Research continues on application of agents to protect normal tissues from the effects of radiation. Although promising, efficacy is variable and treatments are expensive. Cost, logistical issues and side effects remain significant barriers to widespread application.

Brachytherapy

Advantages of using high-dose rate (HDR) brachytherapy include decreased overall patient treatment times and less exposure of radiotherapy and hospital staff. HDR prostate brachytherapy has the theoretical advantage over permanent seeds of better radiation dose tailoring, but requires patient hospitalization as the treatment is generally fractionated over two days. Research continues on the use of breast and brain balloon implants. At this time, lack of mature data, concerns regarding adequate dose distribution, and reimbursement issues limit application. Intravascular brachytherapy for prevention of coronary artery restenosis is being done in the community, but may be replaced by drug coated stents if reimbursement issues can be addressed.